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TESTS OF STRUCTURE FUNCTIONS USING LEPTON PAIRS: W-CHARGE ASYMMETRY AT CDF

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ABSTRACT

The charge asymmetry of W-bosons produced in $p\overline{p}$ collisions has been measured using 19 039 $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decays recorded by the CDF detector during the 1992-93 Tevatron collider run. The asymmetry is sensitive to the slope of the proton's d/u quark distribution ratio down to $x < 0.01$ at $Q^2 \approx M_W^2$, where nonperturbative QCD effects are minimal. Of recent parton distribution functions, those of Martin, Roberts and Stirling are favored over those of the CTEQ collaboration. This difference is seen even though both sets agree, at the level of the nuclear shadowing corrections, with the recent NMC measurements of $F_2^{\mu n}/F_2^{\mu p}$.

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1. Introduction

W^+ (W^-) bosons are produced in $p\overline{p}$ collisions primarily by the annihilation of u (d) quarks from the p with $\overline{d}$ ($\overline{u}$) quarks from the $\overline{p}$. Because the u quark tends to carry a larger fraction of the proton's momentum than the d quark, the W^+ (W^-) tends to be boosted in the p ($\overline{p}$) direction. The resulting charge asymmetry in the production of W's, as a function of rapidity, is related to the slope of the $d(x)/u(x)$ quark distribution ratio at low x ($0.007 < x < 0.24$) and $Q^2 \approx M_W^2$. At these high Q^2, nonperturbative effects are minimal. This measurement complements the F_2^n/F_2^p measured via deep inelastic scattering (DIS).

In this communication, the W charge asymmetry analysis from the 1992-93 data is presented. Relative to the 1988-89 data analysis,[1] there is a seven fold increase in statistics from detector improvements and a luminosity of $\sim 20pb^{-1}$.

2. Charged lepton asymmetry in W Boson Decays

The W-bosons are identified by their $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decays. At the Tevatron ($\sqrt{s} = 1.8$ TeV), the longitudinal momentum of the neutrino cannot be reconstructed. Since the $W^\pm$ rapidity is indeterminate, the charge asymmetry of the decay leptons is measured:

$$A(\eta) = \frac{d\sigma(l^+)/d\eta - d\sigma(l^-)/d\eta}{d\sigma(l^+)/d\eta + d\sigma(l^-)/d\eta} \tag{1}$$

where $d\sigma(l^\pm)/d\eta$ is the cross section for $W^\pm$ decay leptons as a function of lepton pseudorapidity, η.[2] (Positive η is along the proton beam direction.) As $A(\eta)$ is a ratio, normalization uncertainties in both the theory and the data tend to cancel and this simplifies the analysis.

The asymmetry analysis[3] of the 1992-93 data has 19 039 $W \rightarrow e, \mu\nu$ events. These are obtained by selecting isolated, identified, and well-tracked e's and μ's with transverse energy $E_T > 25\ GeV$ and an event wide missing transverse energy in the calorimeter and muon system of $\not{E}_T > 25\ GeV$. To suppress QCD background, events with a jet whose $E_T > 20\ GeV$ are rejected. As the acceptance and efficiencies for detecting l^+ and l^- are found to be equal, $A(\eta)$ in this analysis reduces to the difference in the number of l^+ and l^- over the sum. By utilizing CP invariance, $A(+\eta) = -A(-\eta)$, data at $-\eta$ is combined with that at $+\eta$ to increase the statistics in η bins and to further reduce the effect of small undetected differences in the efficiencies for l^+ and l^-. Studies of the backgrounds and trigger acceptances indicate that systematic errors do not impact the measurement. Systematic errors are negligible relative to statistical errors and corrections to the raw measurement are small (5% or less). The asymmetry measurement is robust and is shown in Fig. 1.

3. Comparisons with Predictions

Predictions of $A(\eta)$ are from calculations of $d\sigma(l^\pm)/d\eta$ which use next to leading order (NLO) QCD partonic cross sections,[4] NLO parton distribution functions (PDF), and the well-known, purely leptonic V-A decay of the W. Experimental cuts and detector effects[3] are also included in the calculations. Figure 1 also shows the asymmetries predicted by the most recent PDF's from Martin, Roberts and Stirling (MRS)[5] and the CTEQ[6] collaboration. Both groups have access to recent DIS results from the CCFR[7] neutrino data, NMC[8] muon data, and HERA[9,10] ep collider data. CTEQ2M and MRSH are post HERA PDF's. To quantify the data's discriminating power to the various predictions, Table 1 shows the goodness of fit χ^2 over seven η bins ($0.2 < |\eta| < 1.7$) and the χ^2 test of the error weighted mean difference ($\Delta\overline{A}$) of the seven data points against calculations.

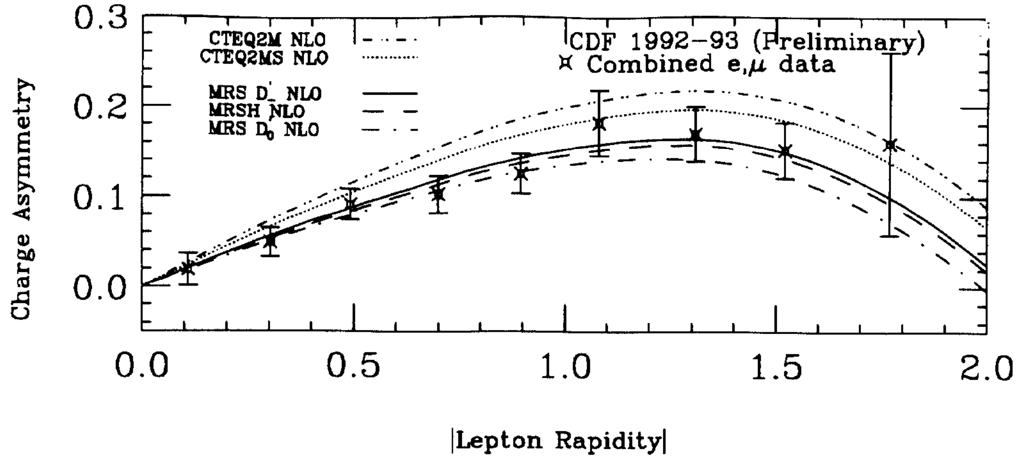

Fig. 1. The measured charge asymmetry, and predictions from recent PDF's. The data are fully corrected for trigger efficiencies and backgrounds. Systematic errors are included.

	$0.2 < \|\eta\| < 1.7$		$\overline{A}$	
PDF Set	χ^2 (7 *dof*)	Prob.	$\Delta\overline{A}$	Prob.
CTEQ 2M	24.	< 0.01	4.6	< 0.01
CTEQ 2MS	11.	0.15	2.9	< 0.01
MRS H	1.8	0.97	-0.1	0.96
MRS D'_-	1.9	0.97	0.5	0.61
MRS D'_0	3.6	0.83	-0.9	0.35

Table 1. χ^2 comparisons of the predicted NLO asymmetries for the most recent MRS and CTEQ distributions. The comparison of the weighted means ($\overline{A}$) is sensitive to systematic shifts, and indicates the MRS H distributions fit the asymmetry data best.

4. Measuring the Proton Structure

The DIS $F_2^{\mu n}/F_2^{\mu p}$ and $p\overline{p}$ W charge asymmetry ($A(\eta)$) measurements provide complementary information on the proton structure. $A(\eta)$ is sensitive to the slope of the $d(x)/u(x)$ ratio[11] in the x range $0.007 - 0.27$, whereas the $F_2^{\mu n}/F_2^{\mu p}$ is sensitive to the magnitude of this ratio. $F_2^{\mu n}/F_2^{\mu p}$ is also sensitive to the $\overline{u}$ and $\overline{d}$ sea distributions, whereas $A(\eta)$ is not.

Recent NMC[8] $F_2^{\mu n}/F_2^{\mu p}$ measurements, both before and after deuteron shadowing corrections,[12,13] are plotted in Fig. 2 along with NLO predictions. Also shown are the PDF d/u ratios after being shifted so that they agree with MRS D'_0 at $x = 0.2$. The PDF's which predict the largest difference between the d/u ratio at small x relative to moderate x, also predict the largest W charge asymmetries. As the MRS and CTEQ predictions on $F_2^{\mu n}/F_2^{\mu p}$ agree (at the level of the 100% uncertainty in the deuteron shadowing corrections), the difference between their d/u ratios are compensated by corresponding shifts in the $\overline{d} - \overline{u}$ sea distributions.

The fact that the charge asymmetry discriminates between PDF's which fit the NMC $F_2^{\mu n}/F_2^{\mu p}$ measurements demonstrates that its sensitivity to the d/u ratio (and not to $\overline{u}$ or $\overline{d}$) at very low x is better than that of the muon scattering experiments. In addition to having very low systematics, the asymmetry data does not have the deuteron shadowing uncertainties, nor is it sensitive to any low Q^2 higher twist corrections.

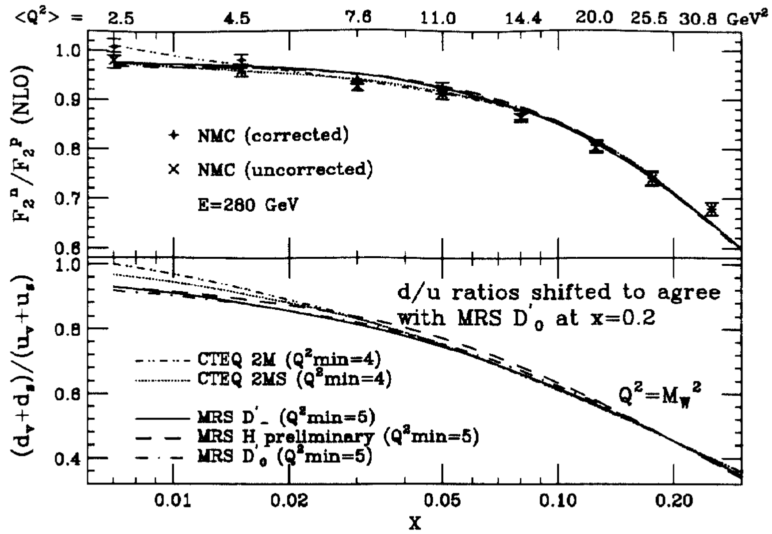

Fig. 2. $F_2^{\mu n}/F_2^{\mu p}$ for some of the most recent PDF's compared to the NMC data and their $d(x)/u(x)$ predicitions. For Q^2 values below Q^2_{min}, the PDF's are logarithmically extrapolated.

CDF has also measured the l^+l^- Drell-Yan differential cross section $d^2\sigma/dMdy_{|y|<1}$,[14] over the mass range $11 < M < 150$ GeV/c^2 using dielectron and dimuon data from the 1988-89 collider run ($\sim$4 pb^{-1}). The measurement is sensitive to parton distributions over $0.006 < x < 0.03$ and it favors recent PDF's which use recent DIS data. However, the statistics are limited. The 1992-93 Drell-Yan data has a five fold increase in statistics and its analysis is in progress. The 1992-93 data, especially in the low mass high rapidity bins, will provide additional constraints on PDF's.

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